APPLICATION OF TERRESTRIAL LASER SCANNER FOR THREE DIMENSIONAL AS BUILT BUILDING MODEL

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To the dearest, the best, greatest, and the only one, my beloved wife
Nurul Zaitul Syeema

To my beloved son, dudeng
Che Ku Muhammad Umar.

And my beloved Umi, Ku, Ibu and Ayah

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ABSTRACT

The purpose of this study was for determine the application Terrestrial Laser Scanner (TLS) in the as-built model buildings in three dimensions based on the Level of Detail 3 (LOD3). Analysis on the measurement of the dimensions of the building was carried out to determine the accuracy of the final results obtained. The aim of this study is to generate a 3D model to help with as-built work, construction monitoring, and for the other user. TLS is used for data acquisition in this study is to achieve the measurement accuracy and more efficient. In addition to reducing hazardous and safety issues that occur in the field. The usual data acquisition methods needs labor intensive and it is time consuming. 3D Model as built building is resulting in Level of Detail 3 (LOD3), can be used for the management of construction, during operation and also in the maintenance phase related to engineering work. With the resulting model, this may increase work efficiency and provide motivation to the person in charge to ensure that work is carried out in accordance with the requirements of employers. Typically the two-dimensional (2D) as-built plans or data is very popular, but in fact it is not so efficient and is less friendly to be used by project owners, landlords and others to review the status of development projects and to see the changes that occur in the construction system. Based on the final results, the model has met the conditions set by CityGML, which is 0.5m accuracy for 3D model in the LOD3. Furthermore, the use of 'plug-ins' were proposed are necessary to enable the switch point cloud data to be processed in the modeling phase of the software modeling. In addition, it is also useful to reduce the size of raw data without reducing the quality of the resulting data.

ABSTRAK

Tujuan kajian ini adalah untuk menentukan aplikasi Terrestrial Laser Scanner (TLS) bagi memodelkan as-built bangunan dalam tiga dimensi (3D) berdasarkan Level of Detail (LOD3). Analisis terhadap pengukuran dimensi bangunan itu telah dijalankan untuk menentukan ketepatan hasil akhir yang diperolehi. Tujuan kajian ini adalah untuk menjana model 3D untuk membantu dengan kerja-kerja seperti yang terbina, pemantauan pembinaan, dan untuk pengguna lain. TLS digunakan untuk perolehan data dalam kajian ini adalah untuk mencapai ketepatan pengukuran dan lebih cekap. Selain mengurangkan isu-isu berbahaya dan keselamatan yang berlaku di lapangan. Kaedah perolehan data biasa memerlukan tenaga kerja yang ramai dan ia memakan masa. Model 3D sebagai bangunan yang dibina adalah menyebabkan (LOD3), boleh digunakan untuk pengurusan pembinaan, semasa pengendalian dan juga dalam fasa penyelenggaraan yang berkaitan dengan kerja-kerja kejuruteraan. Dengan model yang dihasilkan, ini boleh meningkatkan kecekapan kerja dan memberikan motivasi kepada orang yang bertanggungjawab untuk memastikan bahawa kerja-kerja dijalankan mengikut keperluan majikan. Biasanya pelan as-built berbentuk dua dimensi (2D) adalah sangat popular, tetapi sebenarnya ia tidak begitu berkesan dan kurang mesra untuk digunakan oleh pemilik projek, tuan-tuan tanah dan lain-lain untuk mengkaji semula status projek-projek pembangunan dan untuk melihat perubahan yang berlaku dalam sistem pembinaan. Berdasarkan kepada keputusan akhir, model yang dijana telah memenuhi syarat yang ditetapkan oleh CityGML, iaitu ketepatan 0.5m untuk model 3D dalam LOD3. Tambahan pula, penggunaan ‘plug-ins’ yang dicadangkan adalah perlu bagi membolehkan data titik awan di aktifkan untuk diproses di dalam fasa pemodelan didalam perisian permodelan. Selain itu, ia juga berguna untuk mengurangkan saiz data mentah tanpa mengurangkan kualiti data yang terhasil.

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LIST OF ABBREVIATION

μd	-	The difference of mean of sample
$\mu 1$	-	The mean of observation from dataset 1
$\mu 2$	-	The mean of observation from dataset 2
ASCII	-	American Standard Code for Information Interchange
c	-	Speed of light
CEES	-	Centre of Electrical Energy System
Ho	-	Null hypothesis
Ha	-	Alternative hypothesis
ID	-	Identification
ISIIC	-	Institute for Innovative Smart Infrastructure and Construction
KALAM	-	Centre for Built Environment Malay World
LiDAR	-	Light Detection and Ranging
m	-	Distance of the surface where pulse were reflected
n	-	Numbers of sampling
R	-	Range Distance

RGB	-	Red, green and blue
RMSE	-	Root Mean Square Error
ΔR	-	Range resolution
s^2	-	Variance of sample
t	-	Time interval between sending / receiving the pulse
TOF	-	Time of flight
UTM	-	Universiti Teknologi Malaysia
UTM-CRC	-	UTM Construction Research Centre
x_i	-	The element of the sample
$\bar{x}$	-	Mean of samples
x, y, z	-	Coordinate value
z_0	-	z score, the function of the observation value (p-hat).
3D	-	Three dimensional

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CHAPTER 1

INTRODUCTION

1.1 Background

Improvement in the study of spatial data acquisition technology like photogrammetry and laser scanning, which enable more efficient acquisition three dimensional (3D) of data collection in survey work, like in the construction site than with traditional or conventional techniques. In this study, the term of as-built is referring to the actual state of a built building at any time during its life cycle, particularly during its service life (Son *et al.*, 2015). The 3D as-built data which is acquired from field work on construction site can used to establish the geometric properties for building façade. Currently, as-built data obtained also needed for management purposes while projects under construction, after completion of the project, and for the operation and maintenance phase related to civil engineering. For example in the Building Information Management (BIM).

For the purpose of monitoring in site, determine the quality control and the progress of work, a particular application such as a comparison of the building 'as-built' in the actual construction phase of the project with the state ‘as –designed’ state should be done as defined in the contract. As an example of the studies conducted, the progress of the construction activities will be compared with the 3D model 'as-built'

data obtained from the construction site along with design information contained on the building layout plan information. (Pettee, 2005).

In visualization purposes, 3D as-built generated visual presentation is referred to the facade of the building based on the Level of Detail (LOD3) which recommended by City Geographic Mark-Up Language (CityGML). Recently, the Open Geospatial Consortium (OGC) has been established to determine the CityGML 3D city model in the 'five LOD. It has categorized the 3D model from the LOD0 to LOD4 for efficiency in the visualization (OGC, 2012). On Figure 1.1 shows the building structure in formed from LOD1 to LOD4.

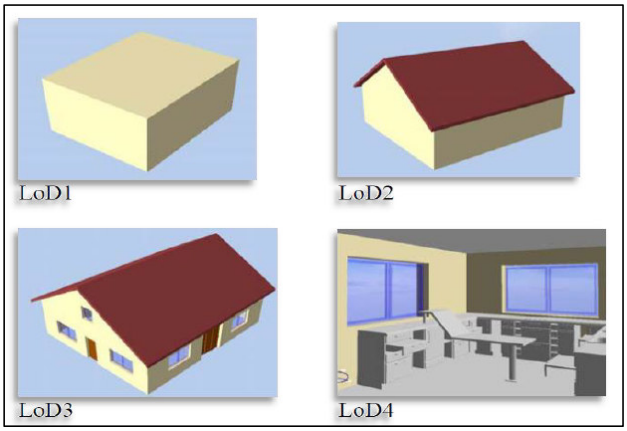

Figure 1.1: Level of Detail for 3D Building Model (Fan & Meng, 2012).

From Figure 1.1 above, each LOD represent a 3D visualization model building can be categorized according to the strength of each model. In order to generating this model, the method of data observations requires special methods and equipment. Therefore, observations using the laser scanner are selected.

The measurement using Terrestrial Laser Scanner (TLS) now become an attraction that grew up. Applications that can be generated based on data TLS very extensive and require much research. One of the main advantages of TLS is a method

that is quick and fast in collecting data, and be able to observe a large region in 3D (Zogg, 2008). The use of TLS in measurement and data collection was very good because it has a promising technique and potential to acceptable as a new measurement technology (Schulz, 2007).

1.2 Problem Statement

The conventional method still used for every on-site surveying work. Although there are many studies about the importance of 3D systems data, there have not been applied in the as-built s work yet. Usually printed two dimension (2D) plan of ABs is generated as the reference, wherein every correction, addition or any changes are noted on the plan. This happens due to various reasons, such as lack of staff, time constraints, work commitments, and budget, but did not assess its needs despite the contractual requirement to provide it.

An as-built plan is usually required by the construction management for the purpose of monitoring progress of work or for the payment of claims. There is some contractor's excellent performance in providing quality as-built records, but the numbers is slightly. The rest did not execute it at its best, where their work was sloppy, illegible, incomplete, or difficult to understand. This may be due to a lack of motivation in the implementation of the work. In addition, there is no standardization of as-built as a reference.

From this reason, it is very important to researchers or practitioners to develop new methods and technologies for use in the production monitoring. Usually, at the beginning of a project development, design documents provided do not give full details of the facility, it left some aspects thereof to the owners and contractors to make a decision later. Since the decision was delayed, it becomes difficult to capture

as-built condition from the entire facility or one of its components in as-built documentation. This situation is common in the case of mechanical, electrical, and plumbing (MEP) system is not fully designed (Bosché *et al.* 2015). In addition, it is sometimes difficult to detect and record changes based on decisions made during construction and thus can produce a final product that deviates from the state as designed. Finally, it can be harder to detect and record adequately in the as-built documentation if irregularities are more subtle and not as a result from the conscious decision (e.g., deviations due to poor workmanship).

The study will conducted for the purpose of implementing new technology in the as-built work process. This is because there is still no as-built database that can be used for further study whether to review the construction work which has been completed, for the in-future development and construction work and for future reference in case of any accident or disaster. Advancement in the study of spatial technology in construction sites such as the use of TLS, enabling more efficient 3D data acquisition in the field of civil infrastructure as-built compared with conventional techniques. (Son *et al.* 2015).

1.3 Objective

Aim of the study is to visualize and generate the 3D model to assist as-built survey services, construction monitoring, and for further user. The objectives for the study are:

1. To generate 3D model of as-built building details from point cloud provided by TLS.
2. To determination the accuracy of as-built model by comparing to existing as-design.

1.4 Research Questions

To meet the objectives of the study, this study will be conducted to answer the following questions:

a. How to scan building efficiently using TLS?
b. How to optimize the quality of the point cloud?
c. How to generate 3D model in LOD3?

1.5 Scope

For the study, UTM Eco-Home on the campus of UTM Johor Bahru as shown in Figure 1.1 is selected as the study location. Based on Office of Corporate Affair of UTM, the construction of house on the concept of "Sustainable Development" was led by Prof. Dr. Muhd Zaimi Abd Majid built with the cooperation of Institute for Smart Infrastructure and Innovative Construction (ISSC), UTM Construction Research Centre (UTM-CRC), Pusat Kajian Alam Bina Dunia Melayu (KALAM) and Centre of Electrical Energy Systems (CEES) and sponsored by a few parties such Bluescope Lysaght, Stagno Tech and Chee Kong Engineering & Construction Sdn Bhd (www.news.utm.my).

The focus in this study is to create a 3D model of building in LOD3. Terrestrial Laser Scanner (TLS) as shown on Figure 1.2 is used as a measuring tools for data collecting. Leica C10 is the selected instrument for data collecting purpose. TLS will produce 3D data in point cloud format. Then the Cyclone software is used for processing stage. Point cloud format is used to generate the 3D detail model of building in a LOD3 by referring to CityGML standard.

Figure 1.2: UTM Eco-home building (www.news.utm.my)

Figure 1.3: Terrestrial Laser Scanner (TLS) instrument.

Final result as for the project is an as-built building model in LOD3. The model would be managed and be ready for visualization in SketchUp 2016. In this study, the 3D as-built model also can be manipulated by user rather than just for visual. Based on the Blueprint provided by CRC team, the 3D model of the building will be reviewed and compared based on the characteristic of the building that has been built.

To ensure that the results obtained meet the required accuracy, quantitative accuracy assessment of dimensional measurement data of the building was carried out. Thus, hypothesis test results obtained are shown in the chapter of results and analysis.

1.6 Significant of Study

Significance of the study is constructed through observation of the deficiencies and improvements that can be improved through of the study to be conducted. The significance of this study is as follows:

i. The technology used in this study can provide the professional surveyor with instruments that can be cost-effective to survey a large complex sites, without compromising the contractors building activities ongoing. With this new technology, it can also provide true, accurate and reliable as-built data and also can save time in the field.

ii. Lately much going cases of negligence and safety issues in the workplace, especially in the construction site. This has increased awareness of safety issues in the workplace. Regarding security concerns, using TLS can avoid to capture data from a dangerous site, such as a site surveyor in a high site, heavy traffic roads and railroad tracks directly. TLS able to observe from a distance that allowed because it applies the concept of contact free measurements device.

iii. Using point cloud data, it would be give all stakeholders the ability to access rich 3D data. Point cloud data would be invaluable in the future to resolve the dispute owners, resident engineers and contractors with valid evidence regarding the placement of structures. For field surveyors, they can complement the 'as-built' survey work quickly and economically. Finally, non-technical users can also manipulate clouds of points and get a deeper insight into the project or site, much bigger than the pictures or videos that are commonly available.

1.7 Brief Methodology of the Study

The study was conducted in four phases, as shown in the following pipeline:

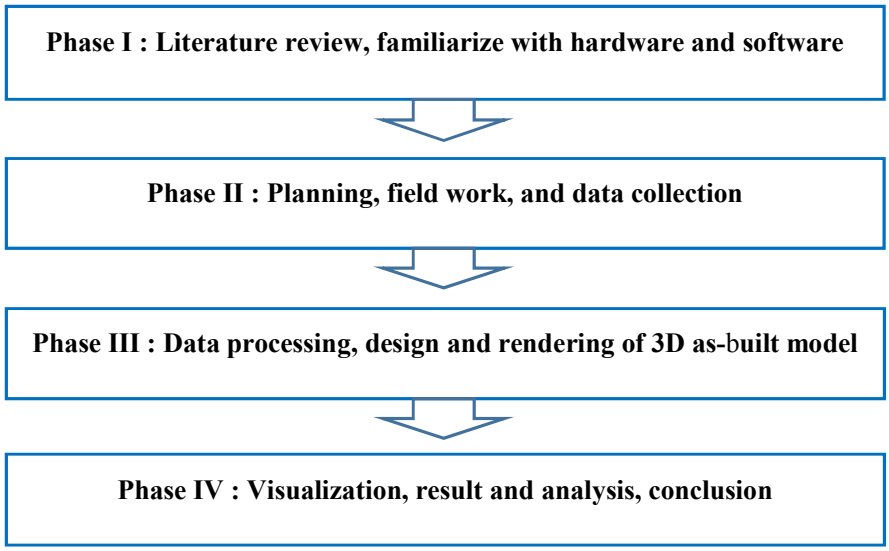

Figure 1.4: Brief methodology used in this study

1.8 Thesis Design

This thesis refers to the five chapters designed to explain the concept, process and results of this study as follows:

Chapter 1: Introduction.

This chapter described briefly the background of study, the problem statement, the scope of the study, and the significant to the study.

Chapter 2: Literature review

This chapter provided the review of fundamental as-built, TLS theory and technique, LOD3 meaning, 3D modelling development and also the review of previous studies related with the study. This chapter will discuss the basic theory and previous study that has been done on how to process the data cloud points in the development of the 3D building model, the use of TLS instrumentation and also to generate 3D modelling.

Chapter 3: Methodology

This chapter describes the methodology of the study. It is involves the methods used in the studies carried out by using a flowchart and also explanation on the working process.

Chapter 4: Result and analysis

Result from the study would be analyse in this chapter. The implementation of the study will be reported in the form of the aid of figures and tables as needed. Final outputs will also be analysed in this chapter.

Chapter 5: Conclusion and recommendation

Lastly, this chapter would discuss the conclusion and recommendation of the study that was conducted. Here also discuss about the answers to all of the questions of the study. The previous works or any reviews that related with this study will be held on the literature review section. The content of those chapters are describe in Table 1.1.

Table 1.1: Study Design and content of those five chapters

Introduction	**Introduction, problem, objectives, research questions, scope, significant, thesis design**
Literature review	**Introduction**
	As built Survey
	State-of-The-Art of 3D Laser Scanning
	3D modelling
	Representing Model in LOD3
	Summary
Methodology	**Introduction**
	Methodology Phases
	Phase I
	Phase II
	Phase III
	Phase IV
	Summary
Result and Analysis	**Introduction**
	Point cloud
	3D Model of Eco-home
	Analysis
	Accuracy assessment
	Summary
Conclusion and Recommendation	**Introduction**
	Conclusion
	Summary
	Recommendation

1.9 Summary

In conclusion, this chapter highlights the background along with the problem statement of study carried out. The matters relating to the making of this study as the research question, the objectives, the scope of the study, significant study and 'brief methodology' is elaborated. Then, on the 'design thesis' elaborates on each of the topics to be discussed at the next chapter.

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